International Journal of Textile
and Fashion Technology (IJTFT)
ISSN(P): 2250-2378; ISSN(E): 2319-4510
Vol. 6, Issue 1, Feb 2016, 25-32

TRANS STELLAR
•Journal Publications •Research Consultancy

COMPARISON AMONG PROPERTIES OF CHLORINE WASHED AND LASER FADED DENIM

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ABSTRACT

Purpose of this work is studying the effect of bleaching and laser denim wash processes, onto functional properties such as tensile strength, for both textile and seamed denim. Experimental used a twill 3/1 100% cotton indigo dyed fabric was bleached using pad and rinse process, as well the same fabric was scanned using CO_2 laser beam. The three denim fabrics, unwashed, bleached and laser washed, were tested using Instron of ASTM D434:1995. Scanning Electronic Microscopy SEM and Fourier transforms infrared spectroscopy FTIR of three fabrics were obtained to investigate the difference in surface morphology of the washed and unwashed denim fabrics. Air permeability ASTM D 737 has been investigated for the three tested fabrics. Main results showed laser fading higher tensile and seam strength, compared to chlorine bleached denim fabric, due to the formation of a polymeric film seen on the fabric morphology, through the SEM. As well the FTIR, of the chlorine bleached denim, showed demolishing of hydroxyl groups OH of the cellulosic chemical structure of tested cotton denim, giving a less tensile strength and higher air flow.

KEYWORDS: ASTM, FTIR, SEM, Washed and Unwashed Denim Fabrics

Received: Jan 31, 2016; **Accepted:** Feb 04, 2016; **Published:** Feb 09, 2016; **Paper Id.:** IJTFTFEB20163

Original Article

INTRODUCTION

Denim wash process can be identified as the worn off look of the indigo dyed twill textile material. Indigo is one of the oldest dyes used by mankind. The current consumption of the dyeis enormous due to the popularity of blue jeans, which are dyed with indigo. The consumption of indigo and other vat dyes reaches about 33 million kg annually (Roessler, A and Jin, X. 2003) and the reduction of indigo to leuco-indigo represents an important type of industrial process which is operated worldwide on a considerable scale (Roessler, A. and Crettenand, D. 2004). The denim wash is traditionally done by means of pumice stone, even though used widely, this process is known for its excess use of water and time consumption. Another way of denim wash can be chemically obtained using bleaching; in the process of bleaching a strong oxidative bleaching agent such as sodium hypochlorite or potassium permanganate is added during the washing with or without stone addition. Problem of yellowing is very frequent due to residual chlorine. Chlorinated organic substances occur as abundant products in bleaching, and pass in to the effluent where can cause environmental pollution (Shalini, N. 2015).

Laser washing is considered as mechanical denim wash, which is regarded as environmentally friendly process. Known from the 1960's, laser is Light Amplification of Stimulated Emission of Radiation; major laser classes are gas, solid, molecular and free electron laser (Pivtoraiko and Rozhkov 2003). The laser beam is moved on the piece of material to be faded by a set of two computer-controlled scanning mirrors. The interaction of the laser beam with the colored material produces a fading in the irradiated area. The residual colorants are expelled

by plasma-induced ablation from the material surface and absorbed by altered ventilation system. The process has three steps; first, computer generation map of the area which will be irradiated with different fluency level function of the desired pattern; second, control of the laser system, scanning system and conveyor system; third, laser-fading process (Dascalu et al. 2000). Laser fading denim is important as it is not a wet process; precisely controlled faded patterns can be obtained. The increasing use of Nd:YAG solid state lasers, and the advent of diode lasers (both producing beams with a near infrared wavelength), meant lasers became available that had a different beam/material interaction with thermoplastics, from that of the far infrared CO2 laser(Hilton et al. 2000). Carbon dioxide CO_2 Laser treatment is a clean production process (Kan C. 2014); in the previously mentioned research experimental results revealed that CO_2 laser treatment is an effective means of producing the color-fading effect in denim garments. The CO_2 laser presents a good alternative due to the interaction characteristics. For the other lasers the equipment is exaggerated and the investment costs are too high, adding the energy costs and maintenance. Besides, the CO_2 has a high efficiency of 10% laser-electricity (Ortiz-Morales et al. 2003). In a previous study by Behera et al. 1997 some important aspects were established for sew ability of denim garments; light weight denim fabric should be sewn with either fine polyester thread or coarser cotton threads. Heavy weight denim fabric should be preferably sewn either with coarsecorespun threads or coarse polyester threads. Cotton threads are not suitable for heavy weight denim. Fine corespun threads are not suitable for denim fabric.

The aim of this study, is to assess the change in functional properties may occur, specifically in tensile strength and air permeability, when denim is processed using Sodium hypochlorite and Carbon dioxide CO_2laser; both seamed area and fabric were examined and compared to the untreated denim. In order to assess the entire denim garment properties, seamed and un-seamed areas, when chlorine bleached and laser faded.

MATERIALS AND METHODS

A commercial denim fabric has been picked, 100% cotton indigo dyed, 28X16 warp X weft density/cm. Seamed line was attained, by means of Siruba 757-D and specifications 516M2-35 of 5-thread safety stitch (401.504) all of 100% polyester 40/2. Turned and sewn a single needle lock-stitch 301, Juki DDL – 5550-1 was used, 100% polyester needle and bobbin 40/3 sewing thread.

Washing techniques used are bleaching and laser fading. Bleaching process was done for 4minutes padding and 1minute rinse, all done at room temperature, then left to dry, squeezing did not take place. 1:50 textile sample to bleaching liquor, ≤ 5% sodium hypo-chlorite was employed in this research. On the other hand, continuous Carbon Dioxide CO_2Laser 10.6 µm was used at speed 250mm/sec, scanning processing mode, min and maximum power were kept constant at 13% while scanning interval 0.1mm. Specification of the three tested indigo dyed denim fabrics; untreated fabric F_{un}, chlorine washed F_{cl} and laser faded F_{laser}, are represented in table 1. These two processes were done onto both seamed and un-seamed samples ofthe warp direction.

Table 1: Specification of Denim Fabrics

Fabric	Weight g/m^2	Std Deviation	Thickness mm	Std Deviation
F_{un}	388	0.58	0.072	0.00
F_{cl}	367	0.86	0.072	0.00
F_{laser}	384	0.58	0.072	0.00

Note: F_{un} donated for the untreated indigo dyed denim fabric, F_{cl} represents the Chlorine washed denim fabric, while F_{laser} is for the Laser treated denim fabric.

Scanning Electronic Microscopy SEM was completed for unwashed, bleached and laser washed denim samples obtained from this research, using Quanta FEG 250, prior to scanning samples were vacuumed and sputter gold for 3minutes, investigating surface change due to bleaching and laser faded treatments, in comparison to untreated indigo dyed denim fabric. Washing methods effect on mechanical properties of the fabric was studied through the measurement of ultimate tensile strength; tensile strength and resistance of seam to slippage were done using ASTM D434:1995 - ASTM D5034:1995, determining strength of seamed and un-seamed fabrics; for all untreated, bleached and laser faded denim samples. Air permeability of ASTM D 737 was done for un-seamed samples. Finally, FTIR (using Burker VERTEX 70 FTIR spectrophotometer), spectra measured in spectral range 400-4000 cm^{-1} in Mid-IR region, with resolution $2cm^{-1}$.

RESULTS AND DISCUSSIONS

Tensile Strength

Tensile strength is defined, by Denton, M. J. and Daniels 2002, as the recorded value at the moment of material rupture; on another words the resistance of a material to stretching in one direction is measured. The surface and inner parts of the fibers within a denim fabric became weak after treatment by stronger laser energy (Jiang et al. 2015).

Table 2: Tensile and Seam Strength of the Three Tested Fabrics

Fabrics	Tensile Strength Kg/f	Std Deviation	Seam Strength Kg/f	Std Deviation
F_{un}	263	23.90	1882.35	
F_{cl}	174	28.14	149	13.83
F_{laser}	235	2.31	176 2.66	

From Table 2 above, laser samples showed a higher tensile strength, as well as the seam strength, when compared to chlorine bleached fabric. This is in line with the resultant data of the SEM and FTIR; where a film has been developed by the laser beam onto denim fabric, while the chlorine bleached process resulted on demolishing of OH groups, leading to lower tensile strength when compared to laser and untreated denim fabric. The highest tensile and seam strength results were denoted for the untreated denim fabric F_{un}.

Air Permeability

Air resistance is one of the major properties of textile materials and an important factor that influences thewearer's feeling of comfort. A higher air resistance means that a smaller amount of air can flow through (Jiang et al. 2015). Air permeability of fabrics is of great significance to thermo-physiological comfort. Depending on the air flow rate through the fabric under a given pressure drop, textile fabrics get their specific character in terms of thermal properties, or more globally in terms of comfort. Comfort of the textiles is a complex property affecting intensively the performance of the final product. In parallel, the air permeability has a significant influence on the drying behavior of fabrics (Cay and Tarakcioglu 2007; Gabr et al. 2010). From table 3 below, air permeability of chlorine bleached fabric increased, the amount of air flowed through the fabric is more than both untreated and laser faded denim. The effect of CO_2 laser caused some air to be blocked due to the film shown in SEM below, the flow of air decreased when compared to bleached and untreated samples. Leading to a sort of uncomfortable feeling by wearer, a sort of overheated effect would result on long term wearing for the laser faded denim. This was the same as the case when laser was used to engrave aluminum foil upon denim fabric in a study by Jiang et al. 2015.

Table 3: Air Permeability of the Three Tested Fabrics

Fabrics	Air Permeability cm3/cm/sec	Std Deviation
F_{un}	3.51	0.298
F_{cl}	4.40	0.164
F_{laser}	3.34	0.142

Scanning Electronic Microscopy SEM

Untreated, chlorine bleached and laser faded denim were all magnified 2000x, are represented in Figures 1, 2&3 respectively. When comparing those SEM, Figure 2 shows optically bright appearance onto the bleached sample using sodium hypo-chlorite, while a burning effect is obvious onto laser faded denim Figure 3, when compared to indigo dyed unwashed sample Figure 1. A film has been made by the laser beam causing the denim fabric to a stronger one; with higher tensile resistance, and lower air permeability, when compared to chlorine bleached fabric, but less tensile strength than the actual untreated fabric. On the other hand, bleaching effect caused by Chlorine washed out indigo dye, caused a less tensile strength fabric and higher air permeability fabric; this can be due to the removal of indigo dyes particles, as well the FTIR showed a demolish in OH groups of cellulose leading to a weaker bleached denim fabric.

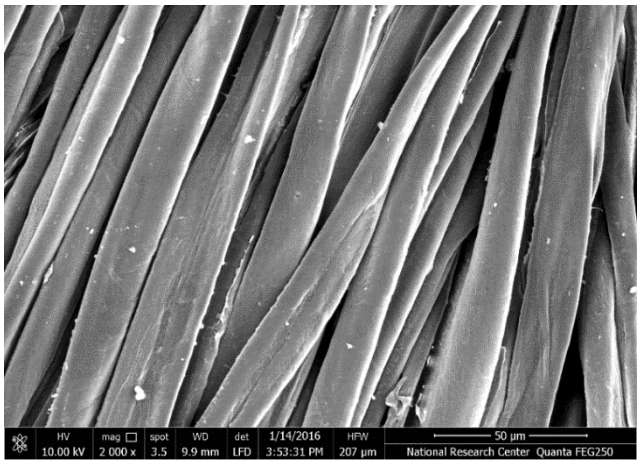

Figure 1: SEM of Untreated Indigo Dyed Cotton Fabric F_{un}

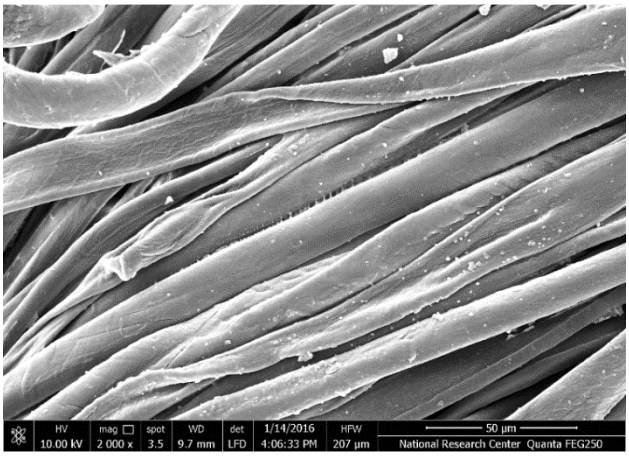

Figure 2: SEM of Sodium Hypo-Chlorite Washed Denim F_{cl}

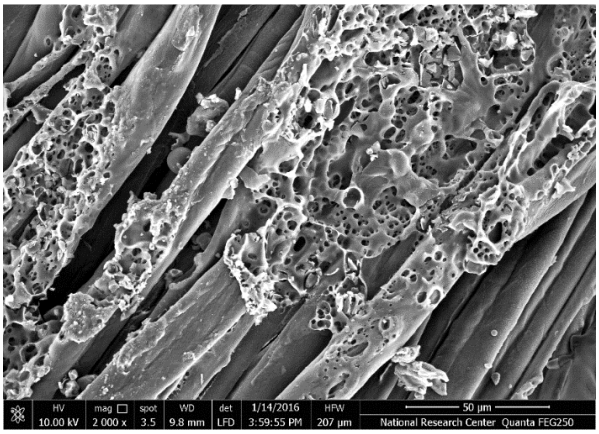

Figure 3: SEM of CO_2 Laser Faded Denim F_{laser}

The sewn areas reacted similarly, in terms of seam strength, for the laser faded and chlorine bleached washed denim, when compared to the untreated indigo dyed denim fabric. In line with the results of a previous study, by Jiang et al. 2015, the experimental results revealed that the changes in mechanical properties are mainly related to the molten and evaporated surface laminated aluminum foil and different sizes of cracks, wrinkles and pores formed on the fiber surface with the increment of laser energy applied. As well a study by Helton et al. 2000, the CO_2 laser beam is absorbed at the surface of the plastic, relying on conduction to heat through thickness of the material, which results in decomposition, vaporization and charring, before any significant depth of material is melted. However, thin polyolefin films, of 0.1mm thick, have been successfully welded with a CO_2laser at speeds up to 500m/min. From the previous researches laser beam causes a melting effect on polymer, by turn can lead to the formation of a thin film, as seen in the SEM Figure 3 above, when compared to untreated and chlorine bleached cotton fabric; this can be due to the presence of synthetic indigo dyes within warp yarns of the cotton fabric.

Fourier Transforms Infrared Spectroscopy FTIR Analysis

The development of the laser as an industrial heat source has resulted in a range of applications that utilize the precise, controllable energy it delivers (Hilton et al. 2000); at the same time environmentally friendly. On the other hand chlorine is shown as a process which should be eliminated, it is considered one of the polluting processes. In order to investigate the chemical effect of laser fading and chlorine bleaching processes on the surface of the 100% cotton denim fabric, FTIR analysis was carried out. Surface morphology, of the untreated, laser faded and Sodium hypochlorite bleached denim, was investigated and represented in the Figure 4.

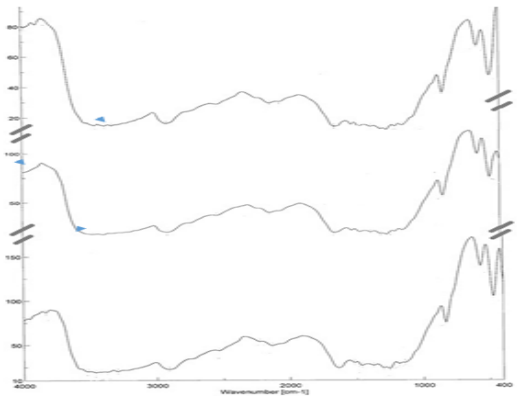

Figure 4: Untreated, Bleached and Laser Faded Indigo Dyed 100% Cotton Denim Fabric

The chlorine bleached sample has been lessened in terms of functional groups, at frequency3831 cm^{-1} non-bonded hydroxyl group OH, of the untreated denim was demolished by bleaching wash process, while laser fading did not affect this OH group. 3323 cm^{-1} acetylene CH has occurred by laser fading, while not found on both untreated nor chlorine bleached samples. 3570 cm^{-1} internally bonded OH group, most likely representing CHOH groups of the cellulosic cotton fabric, appears on the untreated and laser faded denim while demolished by chlorine bleaching process.

CONCLUSIONS

A comparison has been made between examined fabrics from this study, chlorine bleached and laser faded 100% cotton denim fabric, to the untreated indigo dyed one. Even though CO_2 laser is an expensive technique, it is environmentally friendly and fast compared to conventional denim wash. Sewn lines and fabrics were tested. The tensile strength of fabric decreased by a fewer value when laser is used owing to a polymeric film of acetylene developed, with development of CH, on top of warp yarns of denim fabric, while the weft yarns expected to play a role of adhering to the developed film; also the comfort properties represented by air permeability decreased. Chlorine bleached fabric was found to demolish some bonded and un-bonded OH functional groups of the cellulose, leading to less tensile strength, and higher flow of air through inter yarns.

In conclusion, CO_2 laser fading would be a better technique in terms of tensile and seam strength, when compared to Sodium hypochlorite bleaching process, even though comfort properties of air permeability is affected negatively. The Fourier transforms infrared spectroscopy FTIR showed the burning effect causing a film on top of the CO_2 laser faded denim.

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